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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

SHAFT-SINKING METHODS AND COSTS, AND COST OF PLANT AND EQUIPMENT AT THE MACASSA MINE, KIRKLAND LAKE, ONTARIO

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G. A. HOWES AND CHAS. F. JACKSON

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DEPARTMENT OF COMMERCE - BUREAU OF MINES

SHAFT-SINKING METHODS AND COSTS, AND COST OF PLANT AND EQUIPMENT AT THE MACASSA MINE, KIRKLAND LAKE, ONTARIO[1]

By G. A. Howes[2] and Chas. F. Jackson[3]

INTRODUCTION

This is one of a series of circulars dealing with the cost of equipping and developing mining properties in the United States and Canada, prepared and published by the Bureau of Mines in cooperation with various mining and exploration companies. This group of circulars is designed to supplement an earlier series which covered the methods and costs of mining and milling at a large number of producing properties.

ACKNOWLEDGMENTS

The authors desire to thank Robert A. Bryce, president of Macassa Mines (Ltd.), for permission to use the data presented in this paper, and to acknowledge the cooperation of A. J. Keast, under whose direction as manager the plant was installed and equipped and the shaft was sunk to a depth of approximately 2,000 feet.

PURPOSE OF SHAFT

The shaft was sunk to develop the Macassa property along the extension of the main Kirkland Lake fault zone to the west of the active producing properties in the Kirkland Lake district.

Geological indications, together with the desirability of having an operating shaft centrally located on the property, favored sinking the shaft 2,500 feet west of the eastern boundary. The property of the Kirkland Lake Gold Mines (Ltd.) adjoins the Macassa on the east and is the deepest mine in the district, being developed to a depth of about 4,900 feet.

During the sinking of the Macassa shaft a drift was driven from the 2,475-foot level of the Kirkland Lake Gold mine westward along the ore zone to intersect the new shaft at a depth of approximately 2,500 feet. The sinking and drifting were timed so that shaft and drift would reach the objective point at the same time and connect. When this connection was made there was thus a vertical block of ground approximately 2,500 feet long by 2,500 feet high which could be rapidly explored and developed from the shaft and drift.

GEOLOGICAL FORMATIONS

The shaft was sunk through shallow overburden to solid rock. It then passed through 650 feet of conglomerate, 1,040 feet of igneous rocks, and through conglomerate for the balance of the distance. The conglomerate was hard, especially in the lower part of the shaft,

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while the igneous rocks were easy to drill. The ground was for the most part firm, but in the igneous rocks excavation and timbering were followed promptly by close lagging of the sets. At one point in the shaft a heavy flow of water was encountered which required the injection of cement to hold it back.

PREPARATION PERIOD

Before the shaft site was definitely decided upon, considerable diamond drilling had been done to determine the geological formations and structure. The shaft was located within 200 feet of one of the drill holes and the character of the formations to be encountered was thus approximately known in advance of sinking operations.

The surface at this location was covered with second-growth spruce, poplar, and birch. An area of about 8 acres was cleared to prepare the site for the erection of mine buildings, for rock-dump room, and as a protection against fire. The wood cleared from this area was utilized for fuel during the winter months.

Materials, plant equipment, and supplies were hauled over 1 mile of improved government road and about a half mile of mine road. The cost of building the mine road and clearing the site was $2,297.

BUILDINGS

Proximity to the town of Kirkland Lake made it unnecessary to construct camps at the property. Ten small buildings were constructed to house the mine plant and office, as follows:

Building	Size, feet	Type of construction
Office	20 x 20	Frame: 2 x 4 inch joists, rafters, and studding. Covered with fir and good-quality roofing; finished inside with gyproc.
Hoist and compressor house	30 x 50	Do.
Dry house	19 x 25	Do.
Boiler house (for heating plant only)	25 x 17	2 x 4 inch spruce lumber; covered outside with good-quality roofing.
Blacksmith shop	17 x 22	Do.
Topman's house	11 x 11	Same as office.
Pump house	10 x 8	Same as boiler house.
Substation	12 x 12	Same as office.
Powder magazine	14 x 16	Same as boiler house with addition of a good jack-pine lumber floor.
Cap house	6 x 8	Same as pump house, but with good floor.

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Cost of mine buildings

Office	$784
Dry house	787
Hoist and compressor house	1,960
Boiler house	380
Blacksmith shop	561
Topman's house	249
Pump house	97
Substation	558
Powder magazine	455
Cap house	23
Total mine buildings	$5,854

Although the structures listed were required in connection with shaft-sinking operations, they were also designed to serve during later underground exploration and development; thus the total costs are not strictly chargeable to shaft sinking. The same is true of the larger items of equipment cost which are listed in the next section of the paper.

SURFACE PLANT EQUIPMENT

Description.- The electrically driven hoist and compressor, transformers and substation equipment, steel sharpener and other shop equipment, surface pipe lines, pumps and heating system, and shaft headframe comprise the principal plant items.

The hoist is a 72 by 36 inch, double-drum, electric hoist having a capacity of 15,000 pounds on a single line at a speed of 1,000 feet per minute and is powered by a 150-hp., 550-volt, 3-phase, 25-cycle induction motor. It is equipped with two Lilly hoist controllers two brake regulators, position indicators, etc.

The compressor is a 20 - 12 by 14 inch angle-compound machine having a capacity of 1,000 cubic feet of free air per minute at 95 pounds.

The shaft house is a 6-post, A-type timber structure, 60 feet high and fully enclosed with painted corrugated-iron sheathing. There are two 6-foot head sheaves and two compartments equipped with the necessary safety doors and chutes for dumping the sinking buckets.

Substation equipment consists of two 11,000 to 575 volt, 25-cycle, 200-K.V.a., outside-type oil transformers with lightning arrestors, outside poles, and insulators and the usual inside switchboard equipment.

Surface Plant Equipment Costs

The following figures cover the costs of plant equipment, including freight and haulage and the cost of installation.

Equipment	Cost
Office equipment	$636
Hoist and installation except foundations	25,548
Hoist foundations	1,275
Headframe	2,938
Compressor and installation (except foundations)	7,649
Compressor foundations	845

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Blacksmith shop equipment:	
Forge, small tools, etc.	337
Drill steel sharpener	2,462
Dry-house equipment (stove)	23
Cap house	75
Substation equipment	6,528
Water-supply system	327
Miscellaneous surface equipment	119
Surface track	57
Surface pipe lines	773
Surface pumps and motors	399
Heating system	827
Total surface plant equipment	$50,810

UNDERGROUND EQUIPMENT AND COST

Sinking equipment consisted of the usual rock drills, hose and accessories, drill steel, sinking buckets and crossheads, pumps, signaling system and small tools. The crossheads were of special construction and were designed to prevent the bucket from catching against the shaft timbers during hoisting. The construction is shown in Figure 1.

The cost of underground equipment is here itemized:

Equipment	Cost
Rock drills, drill columns, and accessories; including 5 new 3 1/2-inch drifter machines	$2,282
Drill steel (4 1/2 tons)	1,095
Underground pumps and motors	3,137
Two 1 1/2-ton mine cars (on rock dump)	453
Three 3,000-pound sinking buckets	300
Total	$7,267

Note: The crossheads, blasting set, hoisting signals, mine tools, and drill steel were written into the operating costs and are included in the sinking costs, Table 1.

Summary of Preparation, Plant, and Equipment Costs

Preparation, plant, and equipment costs are summarized as follows:

Mine road and clearing site	$2,297
Buildings (not including headframe)	5,854
Plant equipment including headframe	50,810
Underground equipment	7,267
Total	$66,228

SHAFT SINKING

Actual shaft sinking was begun on May 25, 1931, and was completed on August 9, 1932. Shaft stations were cut at 250-foot intervals, and the total depth was 2,489 feet. During January, 1932, an advance of 205 feet was made.

The shaft is 9 by 17 feet, rock dimensions, and is timbered with 8 by 8 inch framed B. C. fir timber sets, 16 feet 3 inches by 6 feet 9 inches over-all dimensions. It is divided

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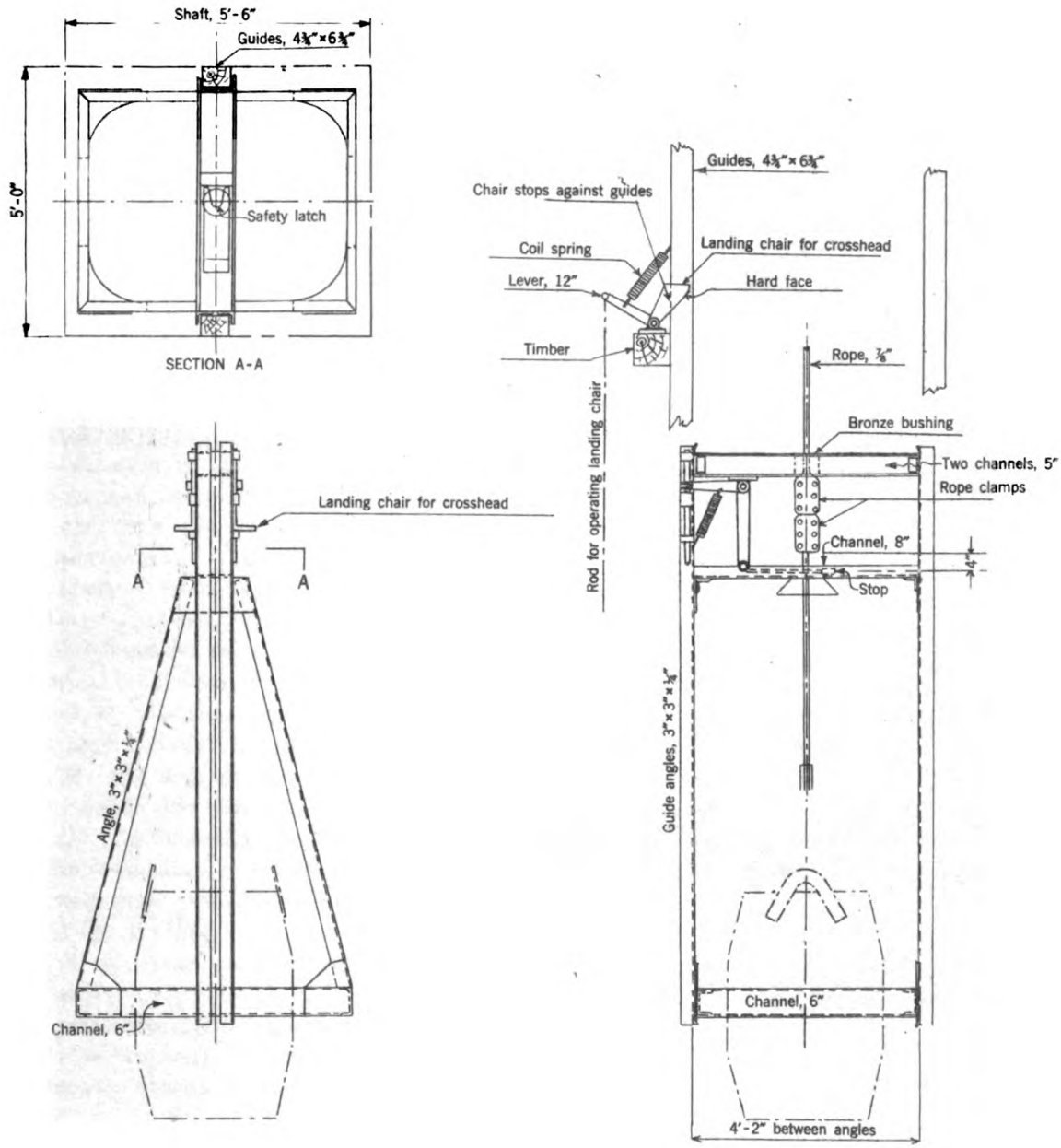

Figure 1.—Special crosshead

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into two hoisting compartments each 5 feet 6 inches by 5 feet in the clear, and one pipe and manway compartment 5 feet 6 inches by 3 feet 9 inches, as shown in Figure 2. Sets are spaced on 7-foot centers and bearing timbers are installed 250 feet apart, or immediately below the level stations. The manway is separated from the hoisting compartments by 1 by 7 inch sheathing and the outside lagging is of 8-inch round spruce poles.

The manway compartment has landings at every 14 feet. The ladders are 16 feet long and are made of 2 by 4 inch spruce with 1 by 3 by 16 inch rungs.

Pipe lines consist of a 6-inch air line, a 4-inch water-discharge column, a 1½-inch water line to supply the rock drills, and a 16-inch galvanized-iron ventilating pipe with stove-pipe joints. Tees were inserted in all pipe lines opposite the various levels (stations for which were cut at 250-foot intervals) to provide connections for later crosscutting and drifting operations.

Ventilation.- An exhaust fan driven by a 7½-hp., 550-volt, a.-c. motor was installed at the shaft collar to draw smoke through the 16-inch galvanized-iron pipe. The fan was turned on after each blast, and the men returned to work within one-half hour after blasting. The time thus saved soon repaid the initial cost of the fan and pipe.

Sinking Practice.- The shaft was excavated by hand to bedrock, which was within 2 feet of the surface at one end of the shaft and within 10 feet at the other end. A small air-driven tugger hoist was then used to sink to a depth of 40 feet below surface prior to building a concrete collar and erecting the regular headframe, and while the regular hoist was being installed. The concrete collar is 15 feet high, extending from solid bedrock to approximately 5 feet above the original surface.

After installation of the hoist and headframe, sinking was carried on regularly on three shifts of 8 hours each. Each shift consisted of six miners, one of whom acted as shift leader, and all of whom worked under the direction of the mine superintendent. A deckman was employed at the shaft collar on each shift and during mucking and timbering periods was assisted by a helper in tramming the rock to the dump and in handling timber. The deckman also cared for the dry and the heating plant.

A topman was employed regularly on day shift but was on call at all hours of the day and night. His duties included rock-drill repairing, pumping, and general utility work.

One blacksmith sharpened the drill steel and performed general blacksmithing work. When there was heavy work to be done - on the average about one day per week - a helper was engaged by the day.

One hoistman on each of the three shifts operated the hoist and looked after the air compressor. One of the hoistmen ranked as a boss and was responsible for the care of the hoist and compressor equipment.

An accountant had charge of the stores, timekeeping, and other office work, and kept the company accounts.

Cycle of Operations

As already stated the shaft crew was composed entirely of miners; that is to say, of men who were competent to perform any work in the shaft. Each shift therefore simply carried on the work from the point at which the preceeding shift left off, whether that work was drilling, mucking, or timbering. Drilling and mucking usually proceeded steadily for five to seven days, or until the bottom of the shaft was 35 to 40 feet below the last set of timber. The shaft was then timbered to within about 10 feet of the bottom.

Drilling.- The type of round found to be the most efficient in breaking the ground is shown in Figure 3. An average of 38 holes was drilled per round, 16 of which were cut holes and 22 of which were square-up holes. With six men in the shaft using four drills, the

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average drilling time, including time consumed in taking down drills, gear, and steel, was 4½ hours. Five drill machines were taken down in order to provide a spare machine in case of breakdown. These machines were 3½-inch, water-Leyner type drifters, equipped with plugger handles. After each drilling period the machines were sent to the surface where they were carefully inspected, overhauled, and oiled by the topman. Any broken parts were immediately replaced and the machines put in first class shape for use in drilling the next round.

Drill steel was of 1-inch, quarter-octagon section with standard cross bits. Four 2-foot steel changes per hole were used to a depth of 2,000 feet, at which depth the rock became so hard as to require five changes. The changes and bit gages were as follows:

Changes	0 to 2,000 feet		Below 2,000 feet	
	Length	Gage	Length	Gage
Starters	2'-6"	1-7/8"	2'-0"	1-7/8"
Seconds	4'-6"	1-3/4"	3'-6"	1-13/16"
Thirds	6'-6"	1-5/8"	5'-0"	1-3/4"
Fourths	8'-6"	1-1/2"	6'-6"	1-11/16"
Fifths	-	-	8'-6"	1-5/8"

An average of 195 pieces of drill steel was used per round. Drills, steel, scaling bars, and tools were lowered and hoisted in one of the sinking buckets.

Wet drilling was practiced throughout the operation. Air pressure at the machines was maintained as nearly as possible at 85 to 90 pounds. Air and water were supplied to the rock drills through a header or manifold. Between the drilling periods this header was left at the shaft station nearest to the bottom of the shaft but when required for drilling it was lowered on the end of one of the hoisting cables to a convenient height above the shaft bottom.

One hoisting compartment was used for bailing water during the drilling shift, and the other hoisting compartment contained the header.

Blasting.- Both 40 per cent and 50 per cent gelatin dynamite were employed in 1-1/8 by 8 inch cartridges. Fifty per cent dynamite was used in the cut holes but only occasionally in the square-up, 40 per cent strength being usually employed in the latter. The miners judged the nature of the ground from the way it drilled and thus determined whether 50 per cent explosive was necessary or not in the square-ups.

Delay-action, all-metal detonators (0 to 10 delays) were used and were fired from an electric switch in the shaft house. A cab-tire cable was run from this switch to the bottom of the shaft, additional cable being added as the shaft was deepened. The detonators were connected in series by No. 20 insulated connecting wires. The detonators were placed in a priming cartridge halfway down each hole. They were entirely waterproof and no trouble was experienced with short circuits or misfires. The blasting circuit carried 30 amperes at 125 volts and was closed by a switch having a special connector which could only be inserted after the switch box was unlocked. Each shift leader carried a key to this box and was alone responsible for the blasting. The order of firing is shown in Figure 3, where the circled numbers indicate the number of the delay used in each hole.

A 2-ton blasting set was kept chained to the bottom of the last set of shaft timbers to protect it from flying rock during blasting. This was made of 8-inch channel iron cut and riveted together to match the shaft timbers in plan. During the timbering periods the blasting set was lowered for the required distance with 1½-ton chain blocks, two at one end of the

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set and the hoisting cable at the other.

Mucking.- Down to a depth of 1,900 feet the broken rock was shoveled into barrel-shaped buckets having a capacity of 2,200 pounds each. Three buckets were used, one being at the bottom of the shaft while the other two, one loaded and the other empty, were being hoisted and lowered in balance in the shaft.

Upon reaching a depth of 1,900 feet the shaftmen were delayed while waiting for the empty bucket to be returned. It was therefore decided to increase the bucket load to 3,000 pounds, and three 3,000-pound buckets, 4 feet high and having vertical sides, were placed in service.

Buckets were attached to the hoist cables with strong clevices made from 3 by 1/2 inch mild steel and reinforced with 1/4-inch steel plate welded on the inside, the hole being bored through both. A 1-1/2-inch chrome-steel bolt with a large hexagon nut held the bucket.

As previously stated, six men did the mucking. The cut required from 3 to 3½ hours to muck and contained from 14 to 20 buckets. The square-up was mucked in from 5 to 7 hours and contained from 41 to 54 buckets.

Timbering.- Usually four sets of timber are put in during each timbering period. The blasting set is first lowered far enough to make room for a set; the wall plates are then lowered in a bucket and hung with 3/4-inch, round-iron hanging rods. The end plates, dividers, and posts are lowered, placed, and aligned and the timbers are securely blocked in place with 8 by 8 inch blocking and sawed wedges. Round spruce lagging poles 8 inches in diameter were placed outside the timbers and spaced as required by the nature of the ground in each instance. The average time required to place a set of timber was 2 hours and 30 minutes. The manway and hoisting compartments were lagged off with a solid lining of 1 by 7 inch rough spruce boards. Shaft timbers were framed for the entire shaft by a man working on contract during the early stages of shaft sinking.

Cementing-off Water.- At a depth of about 400 feet a rather heavy flow of water was encountered in the shaft. It entered through a series of narrow fractures in the rock and considerably slowed up shaft-sinking progress. To overcome this, holes were drilled into the shaft walls across the fractures and cement was forced into the holes with a No. 7 sinking pump. This practically stopped the flow of water into the shaft.

Pumping.- Water in the shaft came from the fractures previously mentioned, from the surface, and from the rock drills. The water from drilling was baled from the shaft during the drilling shift. Cement rings were installed immediately above the 500 and 1,000 foot levels, with pipes leading to sumps at each of these levels.

The pump installed on the 1,000-foot level had a capacity of 110 gallons per minute and was only operated about one hour per day on the average. It pumped against a total head of 1,020 feet and was installed in a permanent manner for rehandling water from the bottom levels during later development work.

At the 2,000-foot level a 50-gallon per minute pump, operating against an 1,100-foot head, was installed to relay water from the sump at the bottom of the shaft. This was driven by a 20-hp. motor and pumped to the sump on the 1,000-foot level. A 50-gallon pump, driven by a 10-hp. motor, handles the water from the bottom to the sump on the 2,000 level.

During sinking operations, the 4-inch discharge column was carried down as the shaft was deepened, a length of pipe being added each time timbering was done.

The permanent power cable was installed at 500-foot intervals during sinking, as were the electric signal wires. Until the 500-foot level station and sump had been cut, water was handled entirely by bailing, and hoisting signals were transmitted by an ordinary bell cord to a bell in the hoist room. The power cable is a 3-conductor, No. 8, B. and S., galvanized steel-wire-armored cable. The signal wires were No. 5, 7-conductor cable.

The power cable was secured to the shaft timbers by means of 3/8 by 1½ inch steel clips and the signal cables by 1/8 by 1 inch clips. Both of these cables were in 540-foot lengths

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and were lowered into the shaft on the reels. They were then hoisted up the manway compartment by means of the hoist, the hoisting cable having been swung over into that compartment.

COST OF SINKING

The sinking costs per foot are shown in Table 1, in which the total cost is distributed over the several operations involved. The costs given include part of the cost of a number of items of equipment such as drill steel, sinking buckets, hoisting cable, etc., which have been absorbed into the operating account.

Development costs, whether they be for shaft sinking, drifting, or crosscutting and raising, are usually considerably higher during work purely of a development nature than are similar costs at a producing property, since development work must absorb all the pumping, surface costs, and overhead charges which in the latter instance are borne in large part by ore production. The figures in Table 1 include all such charges.

Table 1.- Shaft-sinking costs per foot sunk (2,489 ft.)

	Sinking labor and supervision	Drill, drill repairs, steel, air and water lines	Power	Explo-sives	Timber	Concrete collar	Other supplies	Total
Drilling and blasting	$10.378	$3.564 (mat'l) 3.062 (labor)	$2.899	$6.367	-	-	$0.218	$26.488
Mucking	10.884	-	-	-	-	-	.166	11.050
Timbering	3.546	-	-	-	6.087	-	-	9.633
Concreting	-	-	-	-	-	0.215	-	.215
Hoisting	2.987	-	2.971	-	-	-	2.224	8.182
Decking and rock disposal	3.570	-	-	-	-	-	.033	3.603
Ventilation	-	1.519	.050	-	-	-	-	1.569
Pumping	-	-	.536	-	-	-	1.698	2.234
Supervision and workmen's compensation	4.810	-	-	-	-	-	-	4.810
Miscellaneous	-	-	.125	-	-	-	.509	.634
Total direct costs	36.175	8.145	6.581	6.367	6.087	0.215	4.848	68.418
Proportion of general charges								2.512
Total cost per foot sunk								$70.930

The drift driven from the adjoining Kirkland Lake Gold Mines (Ltd.) property was driven by and under the direct supervision of the staff of that company on contract by special arrangement, so that all supervision charges were carried by the shaft-sinking operation.

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The scale of wages paid was as follows:

Hoistmen	$5.20, plus bonus depending upon footage.
Deckmen	4.15 Do.
Deckmen helpers	.40 per hour.
Topman	$150.00 per month, plus 20 cent bonus for footage over 150 feet.
Blacksmith	7.00
Surface laborers	.40 per hour.
Shaftmen	6.00, plus bonus.

The bonus scale for shaftmen was as follows:

Footage per month	Wage plus bonus
140	$6.53
160	7.33
180	8.40
200	9.73
210	11.06
220	12.40

The shaftmen paid for their own shovels in excess of a consumption of 12 per month and for all explosives over $5.60 per foot. They earned an average of about $8.50 per shift.

Table 2 gives the costs in units of labor, power, and supplies.

Unit labor costs are given for the month of April, 1932, a typical month, when 171 feet of sinking and a shaft station were completed. Costs do not include the cutting of the station. Other unit costs cover the entire sinking period.

Table 2.- Costs in units of labor, power, and supplies

April, 1932. 171 feet sunk.

Labor:	Man-hours per foot
Drilling, blasting, and blowing smoke	8.52
Mucking	11.53
Timbering	2.61
Bailing water	.65
Miscellaneous and delays	.93
Total shaft crew	24.24
Feet per 8-hour man-shift - shaft crew only,	0.33
Surface crew:	**Man-hours per foot**
Hoistmen	4.44
Dumping and disposal of rock	7.90
Blacksmithing, steel sharpening, drill repairs and general surface	3.28
Supervision and clerical	2.80
Total man-hours per foot surface	18.42
Feet per man-shift, surface	.433
Total crew-shaft and surface:	
Man-hours per foot	42.66
Feet per 8-hour man-shift	.187

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Table 2.- Costs in units of labor, power, and supplies - Continued

Materials and supplies (2,489 feet of shaft):	Per foot of shaft
Explosives:	
Strength	Pounds
40 per cent	19.0
50 per cent	7.7
60 per cent	2.5
Total all strengths	29.2
Timber:	
	Board measure
Shaft sets (8 x 8 inch timber)	85.0
Blocking (8 x 8 inches)	17.2
Sheathing (1 x 7 inches)	5.0
Guides	12.5
Total	119.7
	Linear feet
Round lagging (8 inch poles)	18.0
	Pounds
Drill steel	2.0

Table 3.- Performance Data

Time worked in shaft (2,489 feet sunk)	days	412
Average progress per day of 24 hours	feet	6.04
Progress per round	Do.	4.93
Number of rounds completed		505
Average rate of sinking plus 18 feet of station and 15 feet of crosscutting per month	feet per month	170
Drilling:		
Number of holes per round		38
Number of steels sharpened per round		195
Total drilling per round	feet	300
Drilling per foot of advance	Do.	59.64
Average number of buckets hoisted per round		67.7
Average number of buckets hoisted per foot of advance		13.45

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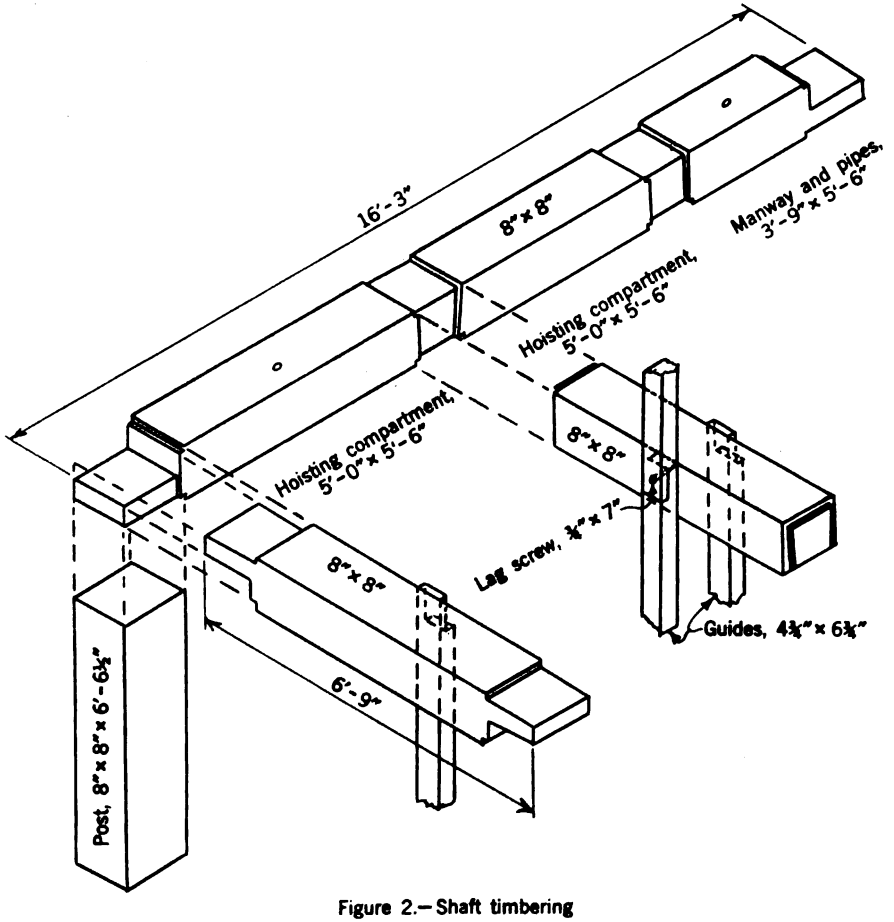
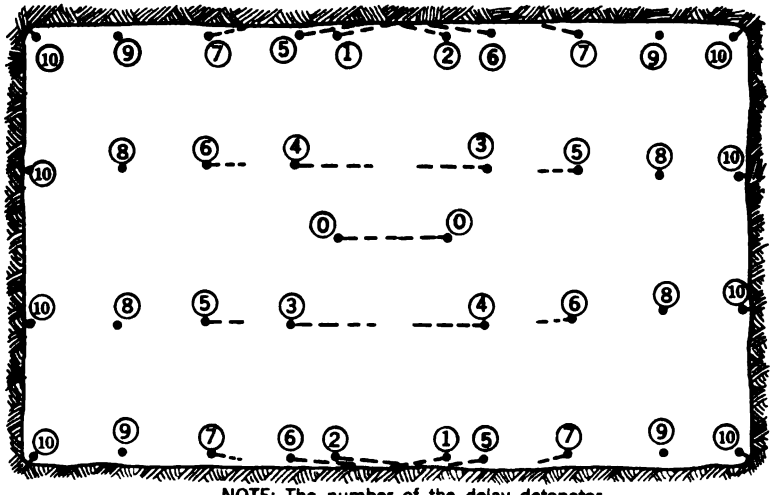


Figure 2.— Shaft timbering



NOTE: The number of the delay detonator used in each hole is shown encircled

PLAN

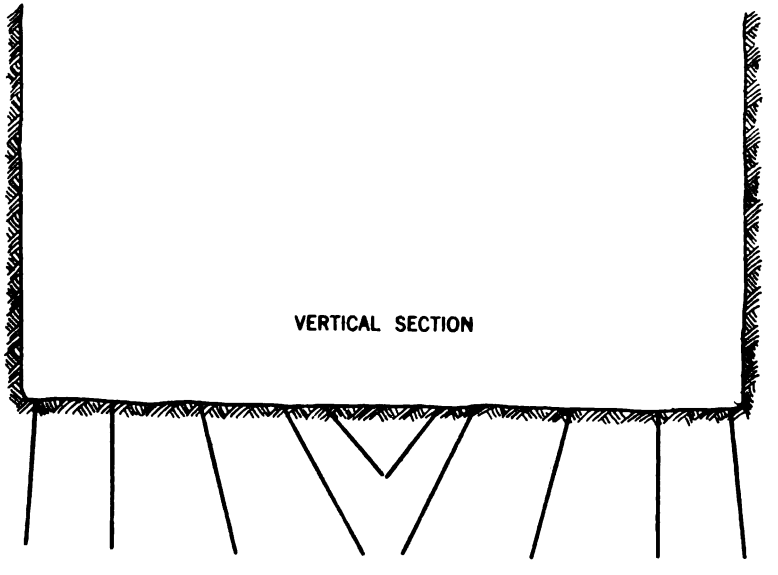


Figure 3.— Shaft round

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